Teaching Energy at Primary School with and without the Use of ICT, Using a Novel Curriculum

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***Abstract*-A new curriculum together with a novel educational software was designed and developed to teach the physical concept of energy. The software design has been discussed previously while a first educational trial to examine the suitability of this new educational material followed. In the present study, 3 groups of students of various ages participated. Experimental Group A was taught the subject with the aid of the novel software, experimental group B was taught the same curriculum without the use of the software, while group C served as control group and had not followed any special teaching except the one provided by the conventional education at school. Herein, a comparison will be made between the results obtained from the experimental group and those of the control group. The study concentrates, therefore, on how well the newly developed curriculum (-as contained in the new software) prepares the students on the subjects taught and tested, and whether or not the teaching with the new curriculum (be that with or without ICT) is more successful than the conventional one.**

Keywords-Web based Learning Environment; Science Teaching; Energy; Energy Curriculum; Misconceptions; Student Ideas

I. INTRODUCTION

Energy is essential in understanding the world. Every living organism (be that plant or animal) needs energy to sustain life. With time, the world's total energy needs are increasing, as human population is also increasing. Overall energy needs are also growing as a result of the increased use of technology. It is well known that the personal standard of living is directly related to energy use. Energy, therefore, is of primary concern in the world economy as much as in everyday life.

Teaching the Physics concept of Energy to primary-school children is notoriously difficult, as students understanding after teaching range from disappointing to even worse, depending on what aspects of Energy one is examining. This is partly due to the fragmented way energy is taught at school, namely repeated disjointed attempts, one for each new form of energy encountered. The nature of Energy (being a "fundamental Physics concept") makes things really worse, as there is no true definition of this Physical entity precisely because it is fundamental. It cannot be, therefore explained by using other (more fundamental) concepts [2]. Conversely, this concept can be used to clarify other (derivative) concepts.

To face such problems, a new curriculum was designed and developed together with novel educational software. The software design aspects of this effort have been previously discussed [1] and an educational trial to examine the suitability of the new material followed. In these trials three groups of students of various ages participated. Experimental Group A was taught the subject with the aid of the novel software (which incorporated the new curriculum), experimental Group B was taught using the same novel curriculum but without the use of the software, while Group C served as control group as it had not followed any special teaching except the one provided by the conventional education at school The present study focuses on how well the newly developed curriculum as well as the new software fare overall, and whether or not the new teaching approaches are more successful than the conventional ones.

The new teaching approach for both experimental groups (computer aided learning, and teaching with traditional methods) had to be implemented during a rather short time-period, which was eight teaching hours for the teaching plus another two for the distribution of pre- and post-tests. Despite the fact that the software was designed to truly cover all aspects of Energy [1], this range is really vast and only a part of this software could be used in the present educational testing. This deals with the renewable and non-renewable energy forms and sources, electricity production methods, and the transmission of the electricity to our homes. This part was selected because a lot of talk about energy conservation and renewable energy sources takes place these days in mass media, often containing misleading information. It is, therefore, considered important for all adults to acquire some basic albeit accurate knowledge about these issues at school. The teaching sequence of the present educational trial was more or less fixed and pre-defined by the researchers.

II. THE SOFTWARE

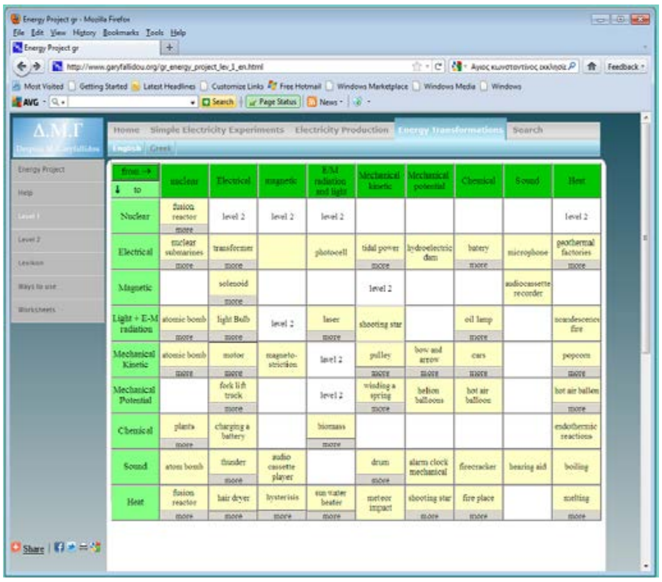


Fig. 1. This is a view of the main screen of "level 1" of the educational software featuring the "active buttons". Level 2 is similar, albeit with different colours and featuring different content

Originally the software had been developed to run from a CD-ROM or from a hard disk. Effort was placed in designing and producing an *"easy-to-use"* piece of software that does

not require in depth knowledge of computers from the user's side, but also something to be exciting enough so as to attract the student's interest and attention. Besides, this type of educational software offers high educational value.

During the educational trial, as a result of extensive discussions with the teachers of the schools that participated in it, it was revealed that it would be more practical for the teachers to access the software through the net. The proliferation of relatively stable ADSL connections in many schools, contributed to the decision taken to modify the software so as to make it available over the net. Other advantages, like users having access to the latest version of the software constituted additional factors contributing to the decision. A small distributable executable file was, consequently, made available containing the interface to access the rest of the software and data-files residing on a web server. This distribution method revealed new disadvantages all of its own. It was quickly realised that very few people were willing to download and run any executable file in general, let alone one coming from an author and a location that was not all that well known so as to be trusted. The software was consequently re-designed again. The page is now written in HTML 4.01, so as to be executable from within the browser. The file that manipulates the "active boxes" or "buttons" in both level 1 and level 2 of the software (see Fig. 1), as well as the pop-ups and the texts are written in Java script. All menus (see Fig. 1) are in Cascading Style Sheet (CSS) manner and are again in Java scripts. In this form, no special software installation is required, the software being, instead, accessible by all common web-browsers, running on any operating system, including mobile telephone as well as tablet ones, be that proprietary or open-code ones.

By talking to the teachers using the software, it became apparent that many teachers prefer to be guided through specific "thematic areas" through the learning material, instead of being offered the extended scientific curriculum on energy in a form of software where they would be able to search for the trail of information appropriate for their lessons, and prepare their own worksheets. Therefore, some distinct thematic areas such as "simple electricity experiments", and "electricity production" have been created and are accessible in the web. The web-based full version of the original program remained available as it was, and it can be reached at: http://www.garyfallidou.org/gr_energy_project_lev_1.html under the "energy transformations" tab, albeit currently available only in Greek language, an English version of which being in preparation.

The full version of the software presented herein is designed with 2 levels of difficulty (in other terms, 2 levels of information depth).

This main program screen (Fig. 1) deals with energy conversions from one form to the other and it is populated by a grid of "active buttons". The (dark green) horizontal coordinate indicates which energy form is the starting point while the (light green) vertical coordinate indicates the type of energy this is converted into. The yellow coloured "active buttons" correspond to either some type of electrical apparatus, or a procedure (be that a physical, a chemical, or biological one), or a device, or even a machine that operates by performing such a transformation. Some places in this two-dimensional matrix are occupied by more than one example, (which would call for more than one "button"). In this case a "more" button underneath the main one (see Fig. 1) will flip to the next example of the same energy-transformation, thereby offering an alternative choice. Household appliances and apparati as well as everyday procedures, and common machines are analysed, by offering detailed explanations of their use of energy and all the energy transformations that happen while they operate. The user can select any of the green or yellow "buttons". By selecting a button, another window appears containing text and pictorial material and, in some cases, a media file is executed. The transformation(s) of energy taking place in each of these apparati (or during natural phenomena) are explained. For the purpose of understanding science the learner should start from a very basic level. Therefore, all texts start from the very basic ideas. For most people when dealing with everyday problems, the scientific explanation of what energy really is seems not to be particularly helpful. What might be more useful instead is a citizen's meaning: an understanding of energy which without emphasizing the abstract, formal mathematical relations [4]. This could nonetheless be quantitative, and it will enable students to consider issues such as transferring energy efficiently, and getting value for what they pay for. It should be stressed here that a lot of effort has been paid so that all texts in the software are both complete and scientifically correct. Most of the texts have extra links to other texts, pictorial material, or media files, that clarifying a certain idea, offering extra info, or more detailed information.

There are also extra links that show to students how to construct something (e.g. a device) or how to perform an experiment. There are also links to texts explaining that not all forms of energy are equally useful (transmission, storage, and transformation efficiency issues), other texts dealing with the energy "production" and distribution, the economics of such industry (be that large or small scale), to safety and environmental issues, as well as the intricate connections of energy usage, production and economic development. The ecological dilemmas concerning energy usage and various commercially available methods of satisfying such demand are also presented. Attention is also paid in clarifying the misconceptions emanating from the mass media. On the main screen of the software, there are also two types of inactive white buttons: the ones without any indication and the ones with the "level 2" indication. The first type would indicate that there are no easy procedures (or machines) performing that type of energy transformation; alternatively, if some such exist they may be too complicated to be included in this (elementary) level of the software. The level 2 indication appears, in this case. As the user navigates through the program, he/she can easily return to the previous screen by pressing the "return" button that is always available.

While the white "level 2" buttons on the main screen are not active, they still indicate that while such a transformation mechanism exists it is not a very common one, or it is a bit complicated and is therefore considered more appropriate for older students, or for more advanced learners. It would have been easy to have all "level 2" buttons being active, but precisely because they are numerous, that it was decided not to, in case younger children switch to the "level 2" screen inadvertently. When users want to visit level 2, all they have to do is select the "level 2" menu, an action that represents a somewhat more conscious decision. Level 2 of the main screen is similar to the one for level 1 but is distinguished by its blue hue and (naturally) contains more advanced examples. Using this screen, users can indulge themselves to all the processes and examples hidden under "level 2" labels in the level 1 main form.

III. Forming the Experimental Groups for the Trial

This study focuses on how well the newly developed Energy curriculum succeeds in preparing students on the subjects taught, and whether or not this new curriculum promotes learning better than conventional curriculum practices. The new energy curriculum is tested in 2 different forms. These are (a) ICT-assisted teaching using specially developed software which is implementing the new curriculum and (b) conventional Lab & class teaching by an expert teacher-researcher following the newly developed energy curriculum. The students that followed teaching (a) above, formed the experimental group A while the students that followed teaching (b) above formed the experimental group B. As both the experimental groups implement the new curriculum, direct comparison between these two groups are of only minor interest, as they would only show if the ICT-based teaching was in any way inferior or if it had a serious fault.

The science subject taught called for careful deliberation as to the details of educational testing. After thorough consideration it was decided to compare the results obtained from both the aforementioned experimental groups with the ones taken utilising university students, these being both mature as well as having completed all formal secondary education. Two reasons weighted most in this decision: a) Due to the nature of the scientific concept taught, the ideas contained in the new curriculum and educational software are presently taught in virtually every science chapter of the existing school curriculum and b) because the new curriculum and software contains basic scientific concepts and ideas that any adult should have obtained during school as well as by utilising non-formal education sources. Because of all these reasons it was considered that any other comparison would have been unfairly biased, and indeed biased in a different way, in respect to which other potential sample would have been chosen. The university students, therefore, formed the control group C.

Another important decision relating to the present study concerned the teacher who performed the educational trials. To minimize bias it was decided that both experimental groups would be taught by the researcher. There were several contributing reasons the most important of which were a) the teaching of the new curriculum (without the help of ICT) demands teachers with a broad knowledge of Science. In order to have any other teacher to perform the trial, some (specially developed) re-training would have been essential, but the efficacy of such teacher-retraining would also have had a need to be proven in practice. Also, b) the teaching with the use of computers demands teachers with a basic understanding of the use of computers and teaching using ICT. Again, an (also untested albeit different) re-training was necessary. c) Research has shown that teachers carry with them their own ideas and misconceptions[5], [6], [7], as for example that nuclear power plant usage is catastrophic, by definition. These ideas would have adversely affected the results of the trial.

IV. Data Analysis

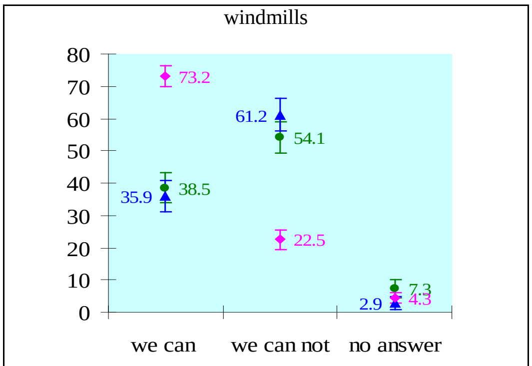
All relevant statistics were calculated using specially constructed software, interfaced with a popular computational and plotting package. The statistical variance was computed and the Bessel-corrected standard deviation was calculated for all data points presented herein. As no experimental measurement can avoid systematic errors, special care was taken (as already explained) so that large systematic were avoided. The systematic errors were reviewed, any possible biases were considered, and the remaining systematic error evaluated. This was set at 1.0%, a figure considered to be fair (if on the low side) and which is consistently comparable with all individual statistical errors. This means that the total error is seen as neither statistics-dominated nor systematics-dominated, and that this holds true for every single data-point presented. The total error was then computed for each data-point by adding in quadrature systematic with individual statistical errors, these two being by definition independent.

The data are presented in histograms, depicting the percentage of students holding a particular idea. The error bars on each point of the histogram represent one total standard deviation on either side of the point, as computed for this single point.

Herein the results obtained from 3 different groups are compared. Experimental group A (primary school students) taught the novel energy curriculum with the use of ICT, with N=109. Experimental group B (primary school students) taught according to the novel energy curriculum albeit using non-ICT teaching, with N=103. Finally group C forms the control group (university students) with N=231. As the samples vary for each of the questions presented, the corresponding size samples are denoted separately at the bottom of each diagram. Naturally, the error bars, being computed individually for each point presented, follow suit.

The questions were formulated in 2 parts. The first part called for a Yes or No response – although there were some students opting not to reply. The second part called for a "short answer" written justification of their opinion. This response was categorised by the researchers in various groups presented herein. Some such responses included either vague or ambiguous answers (classified as such), or some tautologies, i.e. effectively repetitions of the questionnaire's question in a different form. Within the vague answers some truly ambiguous ones were included. On the contrary, answers like "because we can do", or "we already have done so", or "such power-plants already exist" were classified as "tautology-type". In the course of the data analysis, all students' responses of True/False type were classified as either correct or incorrect, while the second part of students responses was processed separately (the "no answer" ones being ignored), as the responses followed an altogether different pattern – see later.

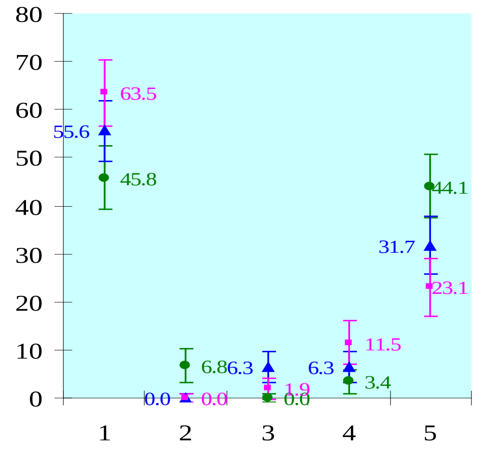
A. Can we electrically power the whole of Greece by just using wind-mills? Justify your answer



Green circles: experimental group A (primary school students) taught with the use of computers, N= 109
Blue triangles: experimental group B primary school students taught with traditional teaching, N=103
Pink rhombi: control group (university students), N= 231

Fig. 2. Students' answers on whether we can electrically power the whole of Greece by just using windmills

We observe that a 73.2% (±3.1%) of the control group believes that we can electrically power the whole of Greece by just using wind-mills while only a 38.5% (± 4.8%) of the experimental group A and a 35.9% (± 4.9%) of the experimental group B hold this idea.



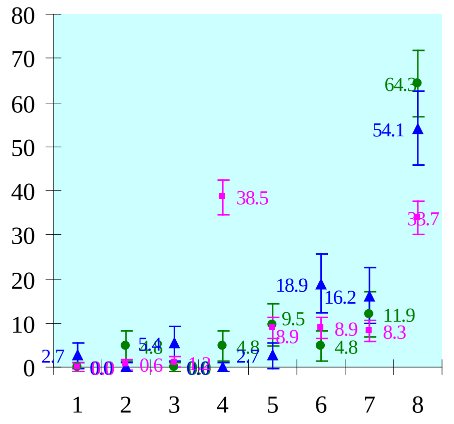
Green circles: experimental group A (primary school students) taught with the use of computers, N=59
Blue triangles: experimental group B primary school students taught with traditional teaching, N=63
Pink rhombi: control group (university students), N=52

1. wind stops
2. need too many/ wind stops
3. other correct answers
4. strong winds
5. no explanation

Fig. 3. Depicts the analysis of the answers of only those participants who correctly answered that we cannot electrically power Greece by just using wind mills. Please note that sample is, consequently, reduced.

Less than a quarter of the control group (52 out of 231) hold the correct opinion, that is the impossibility of powering a whole country by just using wind mills and only half of those could answer why this may be so. Despite that, from the data above showing the distribution of justifications for the opinion held, we deduce that there are not much significant differences between the 3 groups of participants. On the other hand, if we distinguish Group A and compare it with control group C we see some distinct improvement for the students that have been taught with ICT under the new energy curriculum.

The overwhelming majority of the primary school students that answered wrongly that we can electrically power Greece by just using wind-mills, did not justify their answer (see Fig. 4). We also observe that a small percentage of the experimental groups, although answered wrongly the first part of the question, they offered a correct explanation! It should be also mentioned here that a number of participants of all groups has not formed clear ideas about the subject. An 4.8% (± 3.5%) of the experimental group A, an 18.9% (±6.6%) of the experimental group B and a 8.9% (±2.4%) of the control group offer a vague answer while high are also the percentages of the wrong answers. 11.9% (±5.2%) for the experimental group A, 16.2% (±6.2%) for the experimental group B and 8.3% (±2.3%) for the control group.



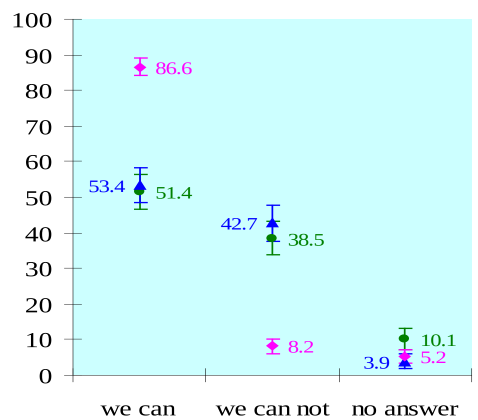
1. wind stops
2. need too many/ wind stops
3. other correct answers
4. strong winds
5. tautology
6. vague
7. wrong
8. no explanation

Green circles: experimental group A (primary school students) taught with the use of computers, N=42
Blue triangles: experimental group B primary school students taught with traditional teaching, N=37
Pink rhombi: control group (university students), N=169

Fig. 4. Depicts the analysis of the answers of only those participants who erroneously answered that it is possible to electrically power Greece by just using wind mills. Please note that sample is, consequently, reduced.

Apart from these, it can be observed that a 38.5% (±3.9%) of the control group believes that the existence of strong winds (many of them add also "on the islands") is enough for the windmills to work (implying that it is even preferable to have good and strong winds), while only a 4.8% (±3.5%) of the experimental group A and a 0.0% (±1.0%) of the experimental group B hold this idea.

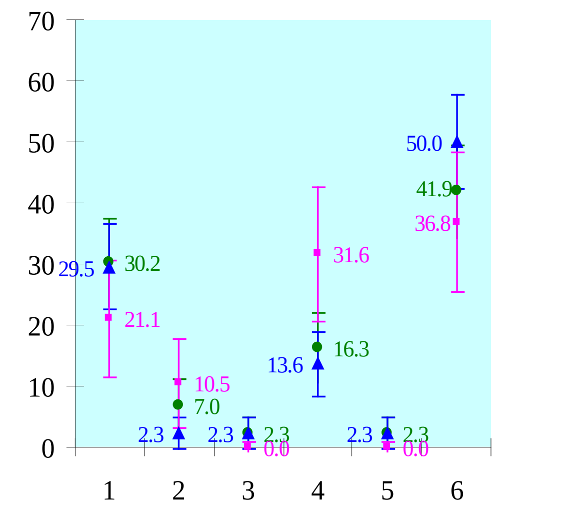
B. Can we electrically power the whole of Greece by just using hydroelectric power-plants? Justify your answer.



Green circles: experimental group A (primary school students) taught with the use of computers, N= 109
Blue triangles: experimental group B primary school students taught with traditional teaching, N=103
Pink rhombi: control group (university students), N= 231

Fig. 5.: Students' answers on whether we can electrically power the whole of Greece by just using hydroelectric power-plants.

The majority of the control group 86.6% (±2.5%) believes that we can electrically power the whole of Greece by just using hydroelectric power-plants while for the experimental group A the percentage is 51.4% (±4.9%) and for the experimental group B 53.4% (5.0%).



1. no, because we have no more rivers to build power-plants
2. yes, because we have many rivers
3. vague
4. wrong
5. tautology
6. no explanation

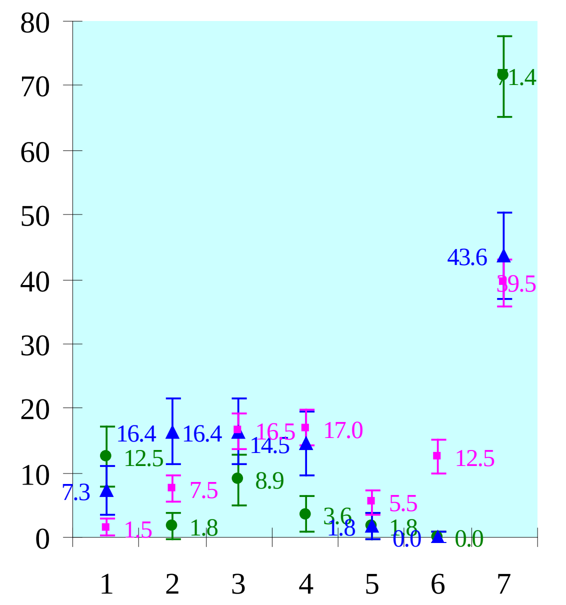
Green circles: experimental group A (primary school students) taught with the use of computers, N=43
Blue triangles: experimental group B primary school students taught with traditional teaching, N=44
Pink rhombi: control group (university students), N=19

Fig. 6.: Depicts the analysis of the answers of only those participants who correctly answered that we cannot electrically power Greece by just using hydroelectric power-plants. Please note that sample is, consequently, reduced.

It should be mentioned here that only 19 out of the 231 university students answered this question correctly, and therefore the overall errors are quite high, as it can be observed by the large error-bars.

Again the percentages of participants that do not justify their answer are high. More specific a 41.9% (±7.7%) for the experimental group A, a 50.0% (±7.7%) for the experimental group B, and a 36.8 (±11.4%) for the control group did not justify its answer. Only a 30.2% (±7.2%) for the experimental group A and a 29.5 % (±7.0%) for the experimental group B offers the correct answer. The errors for the control group being so large we cannot extract any reliable information out of them.

The rest of the answers are wrong. The answer 2 "*yes, because we have many rivers*" is scientifically wrong, but it represents a different category because it is a common misconception among the general public, proliferating from irresponsible talk in the mass media.



1. we have already utilised all the rivers we have.
2. we have many rivers
3. vague
4. wrong
5. tautology
6. we have plenty of water/seas
7. no explanation

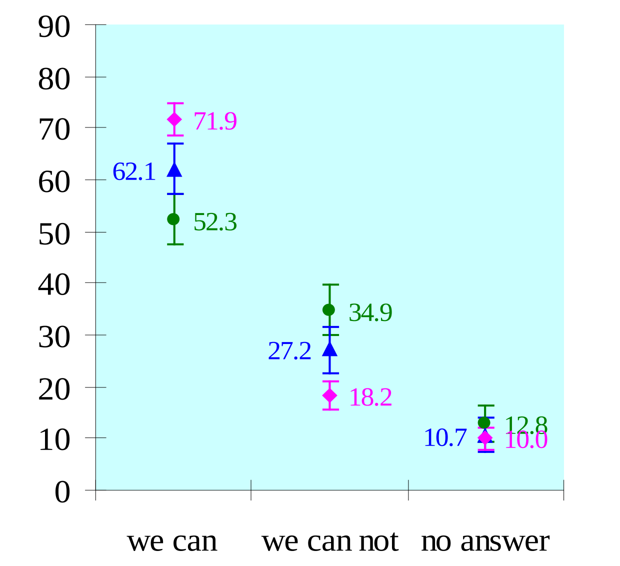
Green circles: experimental group A (primary school students) taught with the use of computers, N=56
Blue triangles: experimental group B primary school students taught with traditional teaching, N=55
Pink rhombi: control group (university students), N=200

Fig. 7.: Depicts the analysis of the answers of only those participants who erroneously answered that it is possible to electrically power Greece by just using hydroelectric power-plants. Please note that sample is, consequently, reduced.

A 71.4% (±6.2%) of the experimental group A, a 43.6% (±6.8%) of the experimental group B and a 39.5% (±3.6%) from the control group do not justify its answer.

The answer 6 "we have plenty of water/seas" is scientifically wrong, but it is consists a different category because it reveals a very strange and serious misconception. A 12.5% (±2.5%) of the control group answers that way. It is obvious that these university students have no idea how a hydroelectric power-plant works. None of the experimental group gave such an answer. We have reasons to believe that university students whose way of thinking is arts-based, and their science knowledge extremely limited, committed such error simply because they lack basic scientific understanding. Therefore, in order to give some kind of response they presumably resorted to analysing the word hydroelectric linguistically. Hydro has to do with the water (a word of Greek origin, really), and since Greece is surrounded by sea it is logical to assume that this water can be used. The moral from this must be that linguistic considerations do not necessarily help in student's scientific understanding.

C. Can we electrically power the whole of Greece by using just thermoelectric power-plants? Justify your answer.



Green circles: experimental group A (primary school students) taught with the use of computers, N= 109
Blue triangles: experimental group B primary school students taught with traditional teaching, N=103
Pink rhombi: control group (university students), N= 231

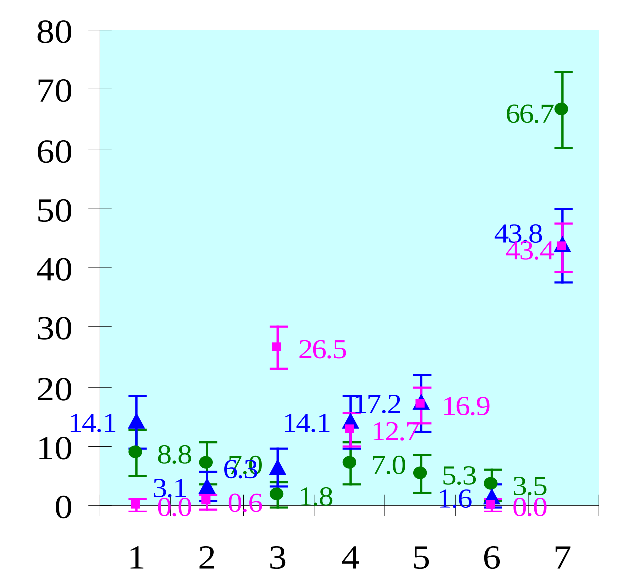
Fig. 8.: Students' answers on whether we can electrically power the whole of Greece by just using thermoelectric power-plants.

The majority of participants 52.3% (±4.9%) for the experimental group A, 62.1% (±4.9%) for the experimental group B and 71.9% (±3.1%) for the control group answers correctly that we can electrify the whole of Greece by using just thermoelectric power-plants.

It had been made clear during teaching that thermoelectric power stations currently produce more than 2/3 of electricity for the national grid and that it was possible for more of them to be built. It was, nevertheless, stressed that such power-plants can only operate for as long as there are still fossil fuels easily accessible, and that the burning of those fossils causes serious problems to the environment. The burning of biomass and waste (i.e. garbage) was also discussed, making clear that students understand that these are small scale endeavours having low conversion efficiency and producing electricity for a limited number of home-users, for any such power-station. It is therefore possible that the students had these in mind when they answered no to this question. This view is further supported by the students' answers in Fig. 9.

For this question also, the majority of the participants 66.7% (±6.4%) from the experimental group A, 43.8% (± 6.3%) of the experimental group B, as well as 43.4% (±4.0%) from the control group did not offer an explanation.

It is worth mentioning that a 26.5% (±3.6%) of the control group does not seem to distinguish between thermoelectric power-plants and photocells (!), while only a 1.8%(±2.0%) of the experimental group A and a 6.3% (±3.2%) of the experimental group B hold such kind of misconception. This is a surprising result, as most of the electricity produced in Greece really comes from thermoelectric power-plants. We believe that, again, the control group participants did not appreciate what "thermoelectric" means and they tried to answer by linguistically-analysing the word. Students in Greece often do that, as it often does work well for them – most of the scientific words have an origin that is ultimately Greek. Even here, "thermo" really is the Greek expression for heat while electric (albeit internationally understood) comes from electron, i.e. amber where static electricity was first observed. Quite perversely, though, this linguistic analysis often leads students up the wrong path, as it is fuelled by their vague understanding on matters of Science. Their assumed train of thought would be that since the sun is hot and the mass media claim that "we should use the energy coming from the sun to produce electricity", therefore it can be deduced that the correct answer would have to do with the "hotness of sun".



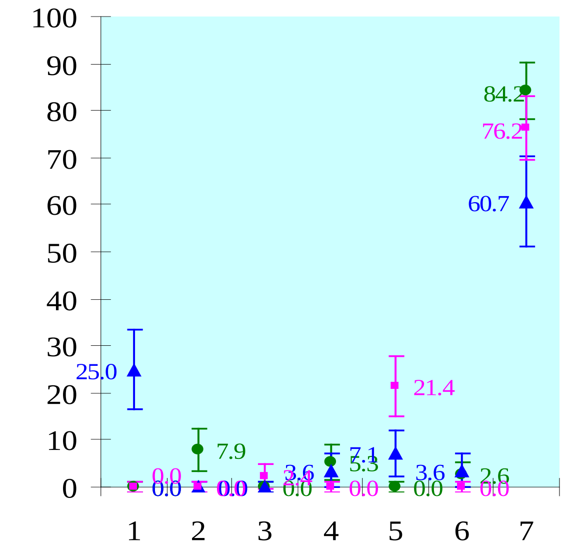
1. environmental consequences
2. till fossil fuels end
3. because sun is hot/sun is free etc.
4. vague answer
5. wrong answer
6. tautology
7. no explanation

Green circles: experimental group A (primary school students) taught with the use of computers, N=57
Blue triangles: experimental group B primary school students taught with traditional teaching, N=64
Pink rhombi: control group (university students), N=166

Fig. 9. Depicts the analysis of the answers of only those participants who correctly answered that we cannot electrically power Greece by just using thermoelectric power-plants Please note that sample is, consequently, reduced.

From these data we can conclude that the experimental groups had a better understanding, but only inasmuch the control group had an abysmal grasp on the subject. For example, a small percentage offers a correct answer that means answers of category (1) or (2). By adding these two categories we end up with a 15.8% (8.8% +7.0%) (±5.0%) for the experimental group A, and to a 17.2% (14.1%+3.1%) (±4.9%) for the experimental group B. On the contrary, looking at the control group, nobody 0.0% (±1.0%) gives an answer belonging in category 1 saying that "we can do it, but with high environmental consequences" while only 0.6% (±1.2%) gives another of the correct answers and says that "we can till the fossil fuels will end" (i.e. students giving

answers in bin 2). The percentage of the students giving either of the two correct answers to the question is so low as to be insignificant.



1. high environmental impact
2. till fossil fuels end
3. confused with sun/hot weather
4. vague
5. wrong
6. tautology
7. no explanation

Green circles: experimental group A (primary school students) taught with the use of computers, N=38
Blue triangles: experimental group B primary school students taught with traditional teaching N=28
Pink rhombi: control group (university students) N=42

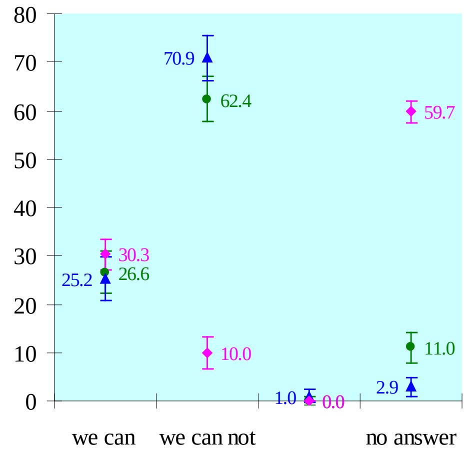
Fig. 10. Depicts the analysis of the answers of only those participants who erroneously answered that it is possible to electrically power Greece by just using thermoelectric power-plants. Please note that sample is, consequently, reduced.

A 84.2% (6.1%) of the experimental group A, and a 60.7% (±9.5%) of the experimental group B, and a 76.2% (±6.7%) of the control group, do not justify their answer

A 25.0% (±8.4%) of the experimental group B gives an answer under category (1). As already mentioned the environmental impact of this type of power-plants was analysed during the teaching. Consequently, we have reasons to believe that these students have understood the subject. On the contrary the students of experimental group A seems that did not visit the relevant page on the software, as this was not essential in order to answer the question in their worksheet.

A 21.4% (6.5%) of the control group offers a wrong answer. It is worth mentioning some of them, like: “we do not have enough volcanoes”, “sun cannot be converted to electricity” etc. which are answers revealing serious misconceptions.

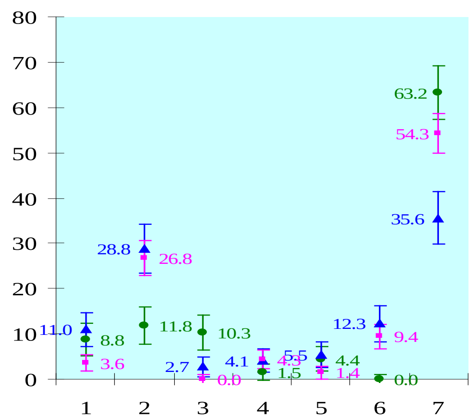
D. Can we electrically power the whole of Greece by just using sea-wave energy generators? (i.e. wave-farms)? Justify your answer.



Green circles: experimental group A (primary school students) taught with the use of computers, N=109
Blue triangles: experimental group B primary school students taught with traditional teaching, N=103
Pink rhombi: control group (university students), N=231

Fig. 11. Students’ answers on whether we can electrically power the whole of Greece by just using sea-wave energy generators.

The majority of the control group 59.7% (±2.2%) did not answer this question. From the data above it is obvious that the majority of the primary school students have a better understanding. A 62.4% (±4.8%) of the experimental group A and a 70.9% (±4.6%) of the experimental group B gave a correct answer.



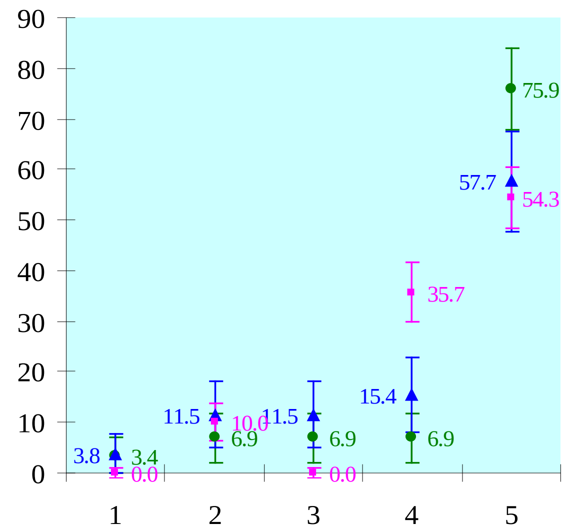
1. research has stopped
2. strong waves in few places
3. environmental impact
4. vague
5. tautology
6. wrong
7. no explanation

Green circles: experimental group A (primary school students) taught with the use of computers, N=68
Blue triangles: experimental group B primary school students taught with traditional teaching, N=73
Pink rhombi: control group (university students), N=138

Fig. 12. Depicts the analysis of the answers of only those participants who correctly answered that we cannot electrically power Greece by just using sea-wave energy generators. Please note that sample is, consequently, reduced.

Despite the correct answer to the first part of the question only an 11.8% (±4.1%) of the experimental group A and a 28.8% (±5.4%) of the experimental group B give a correct answer, while for the control group the percentage is 26.8%

A more plausible answer here would have been that these mechanisms cost a lot (and especially so for maintenance), while only producing energy intermittently. In addition, the required extensive high-power electric grid covering open sea expanses near uninhabited Aegean islands, although possible in theory, it is very expensive, and not that effective overall. Sea maintenance is difficult too, hampered by weather conditions, and also truly intensive due to salt. All these point to high overall cost. At the time the educational trial took place, the research in the field of tidal energy was abandoned by many countries. It started again due to the European directive for lowering carbon-dioxide emissions, now with radically different designs of all type of sizes too, that keep changing all the time as well. The ensuing research in the field of "green energy" can only be applauded, of course, but for the time being such methods are still far from the stage of widespread application.



1. environmental impact
2. vague
3. tautology
4. wrong
5. no explanation

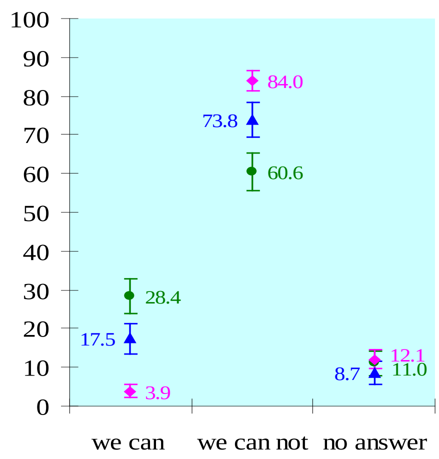
Green circles: experimental group A (primary school students) taught with the use of computers, N=29
Blue triangles: experimental group B primary school students taught with traditional teaching, N=26
Pink rhombi: control group (university students), N=70

Fig. 13. Depicts the analysis of the answers of only those participants who erroneously answered that it is possible to electrically power Greece by just using sea-wave energy generators. Please note that sample is, consequently, reduced.

The majority of the participants 75.9% (±8.1%) for the experimental group A, 57.7% (±9.9%) for the experimental group B, and 54.3% (±6.1%) of the control group do not justify its answer.

It is worth mentioning the high percentage 35.7% (±5.9%) of the control group that offers a wrong justification to this question e.g. "because we have many seas" or "because we have many waves" etc.

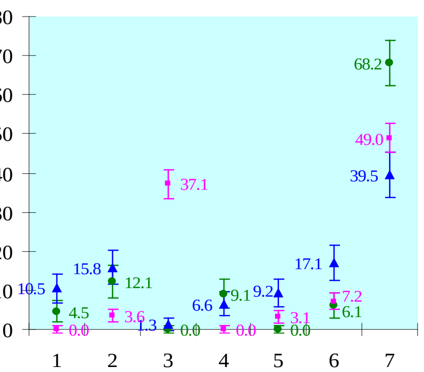
E. *Can we electrically power the whole of Greece by just using tidal energy farms or machinery? Justify your answer.*



Green circles: experimental group A (primary school students) taught with the use of computers, N= 109
Blue triangles: experimental group B primary school students taught with traditional teaching N=103
Pink rhombi: control group (university students) N= 231

Fig. 14. Students' answers on whether we can electrically power the whole of Greece by just using *tidal energy farms or machinery*

The majority of the participants of all 3 groups answer correctly that we cannot electrically power the whole of Greece by just using tidal energy farms or machinery. More specifically a 60.6% (±4.8%) from the experimental group A, a 73.8% (±4.5%) from the experimental group B and a 84.0% (±2.6%) form the control group replies correctly to the first part of the question.

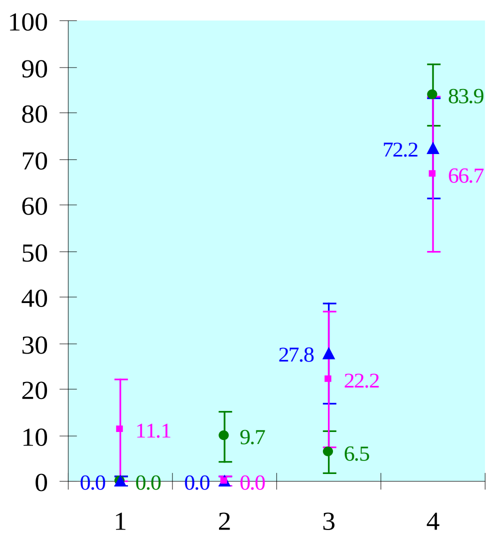


1. research has stopped
2. there are only strong in just a few places
3. do not occur often/mixed with tsunami
4. environmental impact
5. vague
6. wrong
7. no explanation

Green circles: experimental group A (primary school students) taught with the use of computers, N=66
Blue triangles: experimental group B primary school students taught with traditional teaching, N=76
Pink rhombi: control group (university students), N=194

Fig. 15. Depicts the analysis of the answers of only those participants who correctly answered that we cannot electrically power Greece by just using tidal energy farms or machinery. Please note that sample is, consequently, reduced.

The 68.2% (±5.9%) of the experimental group A, 39.5% (±5.7%) of the experimental group B and 49.0% (±3.6%) from the control group did not justify their answer. It is worth mentioning the 37.1% (±3.6%) of the control group that answers (as in category 3) "tides do not occur often", an answer that makes one think that they are mixing the tides, which are periodic and take place 4 times a day, with the tsunamis which only very rarely happen, and the destructive powers of which are beyond human control. The reason of the students' misunderstanding is, we believe purely linguistic: The word "tsunami" (being of Japanese or Indonesian origin) is not really used precisely as such in Greek, being replaced by a translation (a contrived word, really) which is sounding very similar to the word commonly used for "tide", thereby causing the confusion. The only aural-verbal difference between the two scientific terms in Greek is the position of two adjacent vowels, one of which being the same in both terms, so it would be very surprising if students were not confused! Thucydides (writing about the events during the summer of 426 BC at Maliakos gulf) was the first to describe a tsunami (truly in great detail – see the "History of the Peloponnesian war", paragraph (3.89.1-6), [8], [9], as well as the first to offer an explanation of tsunamis arguing (correctly) that earthquakes in or near the sea surely are the only plausible cause of them. Despite all these, two and a half millennia later, the mere lack of a distinctly different and clear term still plagues science education, by not helping children to avoid dismal confusion.



1. do not occur often
2. vague
3. wrong
4. no explanation

Green circles: experimental group A (primary school students) taught with the use of computers, N=31
Blue triangles: experimental group B primary school students taught with traditional teaching, N=18
Pink rhombi: control group (university students), N=9

Fig. 16. Depicts the analysis of the answers of only those participants who erroneously answered that it is possible to electrically power Greece by just using tidal energy farms or machinery. Please note that sample is, consequently, reduced.

The 83.9% (±6.8%) from the experimental group A, and the 72.2% (±10.9%) from the experimental group B and a further 66.7% (±16.7%) from the control group do not justify its answer.

No other useful information can be extracted from the data above.

V. DISCUSSION AND CONCLUSIONS

The first encouraging observation emanating from this research is that computer-based learning environments can be used in teaching science even with primary school students. Pupils seem to **respond quite well** in using the screen and the mouse and they faced no difficulties. Today's children are used to playing "game boys", mobile phone games, and other electronics, and therefore it is easy for them to adapt themselves easily to the computer manipulation, and this is true even for children with no previous computer knowledge.

The two experimental groups were expected to have more or less the same results. This is because they were taught the same subject, albeit with different method. If the teaching in both experimental groups would have taken place by ordinary teachers then the experimental group A would have fared much better. This is because the novel Energy curriculum approach demands teachers with a broad knowledge of Science, and as such this shows a lot more when teachers are not assisted by ICT–based software. As already mentioned, research in Science education has revealed that most teachers (be that young or older) have dire misconceptions on important scientific concepts like, for example, energy. Therefore, in order to have teachers capable to teach Science a major re-training program is needed. On the other hand less time and effort is needed to train teachers to use ICT in their class. Besides, students can come back to the computer based learning environment every time they come up with a new chapter of energy in school curriculum, which in this case acts as a reference point as well as a unifying one. This last point represents a major advantage to using the new software, thereby eliminating a major problem in the teaching of the particular science concept (i.e. Energy), which is that its teaching is fragmented and recurring, creating confusion. By allowing the same school-class to consult the energy software every time a new Physics chapter is introduced, so as a new form of energy is introduced, students should benefit exponentially.

On the basis of the present research, it also seems that pupils from both experimental groups **respond quite well** to the specialised teaching focused on the energy concept, in which the concept is presented in a unified and complete manner.

By looking at the data macroscopically (i.e. overall), we deduce that both experimental groups (primary school students) show better results than the control group (university students), who are supposed to have been taught about all these concepts during all these years at school. It is also clear that the overall results of the experimental groups, although better from those of the control group, are not as good as we would have ideally wanted them to be. As already mentioned the educational trial took place during a limited amount of time. It is quite apparent that there was hardly any time for the primary school students to study further and to revise the subject of Energy as it was taught. Taking this into consideration these results are very encouraging. If more time is devoted to the new curriculum, by repeatedly coming back to the energy software for each new form of energy encountered, primary school students will naturally develop their ideas about energy to be closer to the scientific ones.

As it was already mentioned, any comparison between the two experimental groups has the rather limited scope of showing that ICT assisted teaching is no inferior to implementing the new energy curriculum without the aid of ICT, as opposed to reveal any inherent superiority by teaching using ICT in class. If the teaching using a properly designed and developed computer-based learning environment is as good as the teaching by a highly qualified teacher, this would be sufficient advantage for its usage, as the extra competence from the teacher in science matters is not, then, a prerequisite. Judging from the results this target was fulfilled. Taking into consideration that research in science education has shown that most of the ordinary primary school teachers carry their own misconceptions, it can be deduced that, in general, teaching science with the use of ICT is most beneficial for the students.

The primary school students did not attempt to answer a question if they were not so sure about it. On the contrary, most of the university students did try to offer some type of answer, even if they were not terribly sure about it. This is a technique that students develop anyway, during their high school years. If they do not really know the answer, they respond with something general and rather vague. After all, experience taught them that this might result to some type of grade being offered for their effort, while no reward could possibly result from not attempting anything.

A large number of secondary school-leavers appear to have serious misconceptions on issues relating to the energy concept. It is plainly obvious that (at least as regards the energy concept) the present curriculum system has ***failed*** to provide suitable and adequate energy teaching and understanding. The reasons for the serious misconceptions observed, ***might*** be searched amongst one or more of the following:

- Issues relating to energy are inadequately covered by the school curriculum.
- The school curriculum appears ***fragmented*** on matters relating to energy.
- The exposure to misguided and shallow ***pseudo-scientific articles*** in the mass media, dealing with energy issues.

The participants in the experimental group reacted well in the new way of teaching and to the new computer based learning material. This was expected because children are so used to technological apparati, that even if they had no computer at home, they adjust themselves immediately.

Children asked questions, and they were willing to lose the school-break or even their favourite lessons (e.g. gymnastics) in order to participate in the research. This is not really all that surprising. On one hand, not all students came from areas where parents could afford to buy a computer for their child. Other students did have home computers or even computers for their own use, but in this case they consistently claimed that they could not find educational software appealing enough to them, to the extent that they would be willing to devote some time using it.

As aforementioned in sections 4B and 4C of the data analysis, there are good reasons to believe that university students whose way of thinking is arts-based, and their science knowledge extremely limited, commit some strange errors, the persistence of which may invite some explanation. Although they do not know the correct answer to scientific questions, they do attempt "educated guesses" for what might the correct answer be, by analysing various scientific terms simply linguistically. Students in Greece often do that, as it often works well for them – most of the scientific words have an origin that is ultimately Greek. Words like "thermo", "hydro" and "electro" being really Greek, offer great scope for misinterpretation. Examples of such tremendous misunderstandings arising are "hydroelectric power from the sea" or "thermoelectric power from the heat of the sun", as they have been already analysed above. Such misunderstandings are fuelled by light-hearted opinions on energy matters given freely by various mass media, where no attempt is really made to explain things. There is really no substitute to proper science tuition in schools.

An early observation made during the present research was taking place, was that some teachers demand to be guided through specific "thematic areas", instead of being offered an extended curriculum where they should search for information appropriate for their lessons. As a result, some worksheets dealing with distinct thematic areas were created out of the full-software version. Even more such "guided tours" in special "thematic areas" will become available in the near future. This is in no way invalidating the original concept of having one, all-inclusive, educational software teaching energy in all its forms and all its aspects. On the contrary, it comes as an addition to such concept, in that suggested "tours around Energy concept" are made available to all wishing to learn – students and teachers alike.

Although the results of this research are encouraging, more research is needed here. One such example would be for the computer-based learning environment to be used in other schools with different teachers including perhaps students of younger age, in order to obtain more wide-spread reliable results showing a wider picture, educationally speaking.

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